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Association of portfolio diet score with breast cancer risk: insights from a case-control analysis

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Abstract

Background The Portfolio Diet (PD) is a plant-based dietary approach that has been associated with a reduced risk of cancer-related mortality. The aim of this study was to investigate the relationship between PD score (PDS) and breast cancer (BC) risk in Iranian women, providing insights into the impact of diet on BC risk across different menopausal stages.

Methods The current case-control study included 133 women with newly diagnosed BC and 265 controls without any neoplastic disorders, all of whom were referred to the oncology department of two referral hospitals in Tehran, Iran. A validated semi-quantitative food frequency questionnaire, consisting of 168 food items, was used to gather dietary information. Additionally, odds ratios (ORs) and 95% confidence intervals (95% CIs) were calculated to assess the associations of BC with the PDS and its components, using univariate and multivariate logistic regression analysis.

Results After adjusting for variables in multivariate analysis, a significantly lower association was observed between each unit increase in plant protein intake and the odds of BC in the total population (OR = 0.399, 95% CI: 0.170–0.936). Based on menopausal status, a significant association was found between PDS and the odds of BC in premenopausal women (OR = 0.914, 95% CI: 0.845–0.989). Additionally, in the postmenopausal women, significantly lower odds of BC were observed with each unit increase in plant protein intake in the adjusted model (OR = 0.078, 95% CI: 0.015–0.399).

Conclusions This study provides novel insights into the protective role of PD against BC, demonstrating that a higher PDS is associated with a significant reduction in BC odds among premenopausal women. Plant protein intake also demonstrated a protective effect against BC in both the overall population and postmenopausal women. These findings highlight the potential benefit of the PD as a preventative dietary strategy against BC, particularly emphasizing the role of plant protein.

Keywords Portfolio diet, Portfolio diet score, Dietary pattern, Breast neoplasm, Breast cancer

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Introduction

Breast cancer (BC) is the most prevalent cancer diagnosis among women worldwide [1]. In Iran, BC ranks as the leading cancer among women, accounting for 28.1% of all malignancies [2–4]. The mortality rate for BC has increased [5], reflecting the broader trend observed in the general female population of Iran [6]. Survivors face an increased risk of recurrence, even up to 20 years after the initial diagnosis [7], as well as a heightened susceptibility to weight gain and comorbidities such as cardiovascular diseases (CVDs) and metabolic disorders [8–10].

The increasing incidence and mortality rates of cancer pose significant challenges to health economies, particularly in low- and middle-income countries like Iran. These challenges are exacerbated by factors such as an aging population and the widespread adoption of a Western lifestyle and industrialization [11–13]. Lifestyle factors, particularly diet, are widelyestablished contributors to the etiology of BC. In recent decades, numerous studies have explored the association between specific diets, especially predominantly plant-based patterns like the Mediterranean Diet (MD) and Dietary Approaches to Stop Hypertension (DASH), and the development of BC [14, 15]. It has been suggested that diet may significantly influence BC outcomes. Consistent with dietary guidelines for the general population, adopting a healthy dietary pattern characterized by high consumption of fruits, vegetables, whole grains, poultry, and fish, and low consumption of red meat, refined foods, sweets, and high-fat dairy products could improve the overall prognosis and survival for women diagnosed with early-stage BC [16].

The Portfolio Diet (PD), developed in the early 2000s, is a plant-based dietary approach that combines four cholesterol-lowering components: plant protein, viscous fiber, nuts, and phytosterols [17]. Each of these elements has been endorsed by Health Canada, the United States (US) Food and Drug Administration, and/or the European Food Safety Authority for their efficacy in reducing cholesterol levels or mitigating CVD risk [18–21]. The PD is designed for a 2000 kcal diet and includes 50 g of plant protein sourced from soy products or dietary pulses like beans, peas, chickpeas, and lentils; 20 g of viscous soluble fiber from sources such as oats, barley, psyllium, eggplant, okra, and certain fruits; 45 g of nuts (tree nuts or peanuts); and 2 g of phytosterols, originally provided as enriched margarine [17, 22–25]. A fifth component, 45 g of plant-based monounsaturated fatty acids (MUFAs) from sources like olive oil, canola, high-oleic sunflower oils, or avocados, was later incorporated, which may improve lipid profiles, including high-density lipoprotein cholesterol (HDL-C) [26]. Each component of the PD is included in evidence-based amounts, primarily to lower cholesterol levels and reduce CVD risk. Unlike the MD, which offers general health benefits through a wide variety of plant-based foods, the PD incorporates phytosterols and carefully structured plant proteins, which are not found in the MD. In a groundbreaking prospective cohort study of about 4000 older adults in Hong Kong, adherence to the PD was significantly associated with a lower risk of mortality, particularly from cancer [27].

The PD, rich in antioxidants and possessing anti-inflammatory properties, shows promise in the prevention of BC. However, existing studies largely focus on its connection to CVDs and diabetes, with limited exploration of its specific relationship to BC. This research aims to evaluate the association between adherence to the PD and BC risk in Iranian women, providing new insights into dietary strategies for BC prevention within this demographic.

Materials and methods

Study design and sample

The current case-control study was conducted by recruiting 398 women, including 133 cases with histologically confirmed newly diagnosed BC and 265 controls without any neoplastic disorders, long-term dietary modifications, or alcohol abuse. Cases were selected from patients aged 30 to 65 years who referred to the oncology departments of two referral hospitals (Imam Hossein and Shohadaye Tajrish hospitals) in Tehran. Simultaneously, hospitalized patients in other departments of these hospitals (orthopedic disease, traumas, problems of the nose, eyes, ear, and skin, and acute surgery) who did not have a history of cancer or hormone therapy were chosen as controls. The study sample size was estimated based on the study by Ching et al. (odds ratio (OR) = 0.47, $\alpha = 0.05$, and $\beta = 20\%$) [28].

The patients were excluded if they met any of the following criteria: (1) pregnancy, (2) lactation, (3) a history of hormone therapy, (4) adherence to special diets, (5) energy intake outside the range of the mean ± 3 standard deviations (SDs), or (6) failure to respond to more than 50 items of the food frequency questionnaire (FFQ).

The study protocol was approved by the Ethics Committee of the National Nutrition and Food Technology Research Institute at Shahid Beheshti University of Medical Sciences. Additionally, written informed consent was obtained from all participants. It should be noted that some details of the present study have been previously published [29, 30].

Data collection

The data collection was carried out by trained dietitians through anthropometric assessments and interviews regarding the demographic, lifestyle, and clinical information of participants. These included age (years), marital duration (years), age at first pregnancy (years),

menopausal status (pre- or post-menopause), smoking history (yes/no), breastfeeding duration (months), bra wearing during the day and night (yes/no), family history of BC (yes/no), and supplement use (yes/no). Additionally, physical activity levels were quantified using a previously validated questionnaire, expressed in terms of metabolic equivalent of task-hours per day (MET-h/day) [31]. Height was measured with a non-stretchable meter fixed to a wall (to the nearest 0.5 cm), and weight was measured using a digital scale (with 0.1 kg precision), while the participant was barefoot and dressed in light clothing. Body mass index (BMI) was calculated by dividing weight (kg) by height squared (m^2).

Assessment of dietary intake

A validated semi-quantitative FFQ with 168 food items was used to obtain dietary information [32]. Trained dietitians asked participants to report the frequency of their food intake over daily, weekly, monthly, or yearly intervals for the year prior to BC diagnosis for the cases or prior to hospitalization for the controls. The daily intake of each food item was then calculated and converted to grams (g/day) based on the household measurements [33]. The food composition table of the US Department of Agriculture (USDA) was used to determine the calorie and nutrient content of most foods [34]. For traditional Iranian foods not found in the USDA database, the composition table of Iranian foods was used [35].

PD score (PDS) calculation

The Glenn et al. study provides recommendations for higher adherence to the portfolio dietary pattern [36]. Recommended foods include plant protein (legumes), nuts, viscous fiber sources (such as berries, citrus fruit, eggplant, and oats), phytosterols, and MUFAs from plant sources (e.g., olive and soy oils). The intake of saturated fatty acids (SFAs) and cholesterol sources (including red and processed meats, high-fat dairy, and butter) should be limited [36]. For the PDS calculation, the intake of all six components was calculated as daily servings, except for phytosterols, which were calculated based on daily intake (mg/day) from all FFQ items. A quintile-based approach was used to grade each component: individuals in the highest quintile of five recommended foods (plant protein, nuts, viscous fiber sources, phytosterols, and plant MUFAs) earned five points, whereas those in the lowest quintile earned one point. Conversely, reverse scoring was applied to the food group that should be restricted (SFAs and cholesterol), with those in the highest consumption (quintile 5) receiving one point, and those in the lowest consumption quintile (quintile 1) receiving five points [36]. Consequently, the total points from these components resulted in a score between 6 and 30, with higher scores indicating greater adherence to the portfolio dietary pattern.

Statistical analysis

The normality of variables was assessed using the Kolmogorov-Smirnov test. The characteristics of cases and controls were compared using the chi-square test for categorical variables and either the independent samples T-test or the Mann-Whitney U test for continuous variables. Categorical variables were expressed as frequencies (percentages), while continuous variables were reported as mean ± SD if normally distributed or as median (25-75th percentiles) if non-normally distributed. Univariate logistic regression was used to identify confounders associated with BC. ORs and 95% confidence intervals (95% CIs) were calculated for the associations between BC and PDS and its components using univariate and multivariate logistic regressions. The multivariate regression model was adjusted for variables with a p-value < 0.25 in the univariate regression with BC, including age (years), age at marriage (years), age at first pregnancy (years), breastfeeding duration (years), BMI (kg/m^2), menopausal status (pre-menopause/post-menopause), family history of breast cancer (no/yes), wearing a bra during the day (less than 12 h/more than 12 h), wearing a bra at night (no/yes), vitamin D use (no/yes), omega-3 use (no/yes), and use of herbal medicine (no/yes). Additionally, a subgroup analysis was conducted based on menopausal status (pre-menopause/post-menopause). All statistical analyses were performed using SPSS software (version 26.0), with a significance level set at p-value < 0.05.

Results

According to Table 1, the mean age in the case group was significantly higher than in the control group ($P = 0.032$). Additionally, the control group had significantly higher rates of wearing a bra during the day for less than 12 h ($P = 0.012$) and vitamin D utilization ($P = 0.038$). Moreover, a statistically significant difference was observed between the two groups in terms of plant protein intake ($P < 0.001$) and the PDS ($P = 0.005$).

The unadjusted OR between baseline variables and the odds of BC are reported in Table 2. A significant increase in the odds of BC was observed with each additional year of age (OR = 1.023, 95% CI: 1.002–1.044, $P = 0.029$) and each additional year of age at first pregnancy (OR = 1.041, 95% CI: 1.003–1.079, $P = 0.034$). Additionally, higher odds of BC were found in the post-menopause group compared to the pre-menopause group (OR = 1.588, 95% CI: 1.044–2.414, $P = 0.031$). Furthermore, higher odds of BC were observed in individuals who wore a bra for more than 12 h per day compared to those who wore it for less (OR = 2.287, 95% CI: 1.717–4.467, $P = 0.015$). In contrast, the odds of BC were significantly lower in the population

Table 1 The baseline features of the study participants between the control and case groups

Variables	Cases (*n* = 133)	Controls (*n* = 265)	*P*-value
Demographic features			
Age (years) *	49.51 ± 10.71	47.11 ± 10.09	**0.032**
Marriage age (years) ^	19.0 (16.0–22.0)	18.0 (16.0–20.0)	0.077
Age at first pregnancy (years) ^	20.0 (17.0–25.0)	20.0 (17.0–22.0)	0.055
Breastfeeding time (months) ^	39.0 (20.0–60.0)	48.0 (24.0–70.0)	0.162
BMI (kg/m^2) ^	29.64 (25.96–33.32)	28.52 (25.39–31.64)	0.119
Physical activity (MET-h/day) ^	32.10 (29.10–35.50)	31.42 (29.10-34.98)	0.677
Menopausal status, % &			0.079
Pre-menopause	61 (45.9)	152 (57.4)	
Post-menopause	72 (54.1)	113 (42.6)	
Family history of breast cancer, yes, % &	11 (8.3)	12 (4.5)	0.171
Wearing a bra at day, less than 12 h, % &	12 (9.0)	49 (18.5)	**0.012**
Wearing a bra at night, yes, % &	105 (78.9)	189 (71.3)	0.116
Smoking history, yes, % &	4 (3.0)	9 (3.4)	1.000
Vitamin D, yes, % &	20 (15.0)	64 (24.4)	**0.038**
Omega-3, yes, % &	8 (6.0)	31 (11.7)	0.076
Herbal medicine, yes, % &	25 (18.8)	72 (27.2)	0.083
Dietary intakes			
Energy (kcal/day) ^	2569.13 (2202.80-3107.85)	2459.62 (2136.23-3220.60)	0.615
Plant protein (serving/day) ^	0.29 (0.18–0.50)	0.42 (0.28–0.61)	**<0.001**
Nuts (serving/day) ^	0.18 (0.08–0.35)	0.20 (0.09–0.36)	0.460
Viscous fiber (serving/day) ^	1.58 (1.20–1.99)	1.62 (1.24–2.15)	0.202
Plant MUFAs (serving/day) ^	1.72 (1.21–3.01)	1.92 (1.14–3.18)	0.229
SFAs and cholesterol (serving/day) ^	4.75 (3.24–6.62)	4.51 (2.78–6.33)	0.333
Phytosterols (mg/day) ^	20.02 (13.44–29.43)	22.45 (15.41–30.92)	0.123
Portfolio diet score *	17.12 ± 4.51	18.44 ± 4.40	**0.005**

Abbreviations: BMI, body mass index; kg, kilogram; m, meter; MET, metabolic equivalent of task; kcal, kilocalorie; mg, milligram; MUFAs, monounsaturated fatty acids; SFAs, saturated fatty acids

* Using independent samples T-test for parametric continuous variables, and values are mean ± SD

^ Using Mann-Whitney for non-parametric continuous variables, and values are median (25^{th} -75^{th} percentiles)

&Using chi-square test for categorical variables, and values are numbers (percentages)

that used vitamin D compared to those who did not (OR = 0.556, 95% CI: 0.320–0.966, *P* = 0.037).

The association between PDS and sub-groups with the odds of BC is shown in Table 3. In the crude models, the odds of BC were significantly lower with each unit change in PDS (OR = 0.934, 95% CI: 0.890–0.980, *P* = 0.006) and plant protein intake (OR = 0.275, 95% CI: 0.123–0.616, *P* = 0.002). After adjusting for variables with a p-value < 0.25 in the multivariate (as shown in Table 2), a significantly lower association was seen between each unit increase in plant protein intake and the odds of BC (OR = 0.399, 95% CI: 0.170–0.936, *P* = 0.035).

The association between PDS and the odds of BC based on menopausal status is reported in Table 4. In the crude model, lower odds of BC were observed with each unit change in PDS (OR = 0.896, 95% CI: 0.838–0.958, *P* = 0.001), viscous fiber intake (OR = 0.618, 95% CI: 0.405–0.942, *P* = 0.025), and phytosterol intake (OR = 0.973, 95% CI: 0.950–0.997, *P* = 0.028) in the premenopausal group. After adjusting for potential confounders, a significant association remained between PDS and the odds of BC (OR = 0.914, 95% CI: 0.845–0.989, *P* = 0.025).

In the postmenopausal group, significantly lower odds of BC were found with each unit increase in plant protein intake in both the crude model (OR = 0.134, 95% CI: 0.039–0.467, *P* = 0.002) and the adjusted models (OR = 0.078, 95% CI: 0.015–0.399, *P* = 0.002). No significant associations were found for other variables in both the crude and adjusted models.

Discussion

The results of the present study revealed that higher adherence to the PDS is associated with a nearly 9% reduction in the odds of BC in premenopausal women. Our analysis indicated that each daily serving of plant protein was linked to a 60% reduction in the odds of BC in the overall population and a 92% reduction in the odds in postmenopausal women. However, no significant association was found between the PDS and its

Table 2 Association between baseline variables and odds of breast cancer

Variables	OR	95% CI	*P*-value
Age (years)	**1.023**	**1.002–1.044**	**0.029**
Marriage age (years)	1.033	0.996–1.071	0.079
Age at first pregnancy (years)	**1.041**	**1.003–1.079**	**0.034**
Breastfeeding time (months)	0.996	0.991–1.002	0.158
BMI (kg/m^2)	1.035	0.997–1.075	0.069
Physical activity (MET-h/day)	1.007	0.968–1.047	0.728
Energy (kcal/day)	1.000	1.000–1.000	0.933
Menopausal status			**0.031**
Pre-menopause	Ref.	Ref.	
Post-menopause	**1.588**	**1.044–2.414**	
Family history of breast cancer			0.137
No	Ref.	Ref.	
Yes	1.901	0.816–4.431	
Wearing a bra at day			**0.015**
Less than 12 h	Ref.	Ref.	
More than 12 h	**2.287**	**1.717–4.467**	
Wearing a bra at night			0.104
No	Ref.	Ref.	
Yes	1.508	0.920–2.473	
Smoking history			0.847
No	Ref.	Ref.	
Yes	0.889	0.269–2.942	
Vitamin D			**0.037**
No	Ref.	Ref.	
Yes	**0.556**	**0.320–0.966**	
Omega-3			0.077
No	Ref.	Ref.	
Yes	0.483	0.216–1.083	
Herbal medicine			0.068
No	Ref.	Ref.	
Yes	0.620	0.372–1.036	

Abbreviations: OR, odds ratio; CI, confidence interval; BMI, body mass index; kg, kilogram; m, meter; MET, metabolic equivalent of task; kcal, kilocalorie; mg, milligram; Ref, reference

Significant values are shown in bold

These values are odds ratios (95% CIs)

Obtained from logistic regression

components— such as the consumption of nuts, viscous fiber, plant MUFA, SFA, cholesterol, and phytosterols — and BC risk in the total population.

To our knowledge, this study is the first to examine the potential role of the PD in BC prevention, making direct comparisons with existing literature challenging. As a result, our findings lack direct comparability with other epidemiological studies. Nevertheless, lifestyle factors, particularly diet, are widely acknowledged as contributors to BC etiology. Over the past few decades, numerous studies have examined the relationship between specific diets, especially plant-based patterns, and BC development [1, 2]. These dietary patterns are known to provide antioxidant, anti-inflammatory, and anti-insulin resistance properties, which may protect against BC [3, 5, 6, 37].

In line with our study results, an observational study conducted in the US population reported that higher plant protein intake, particularly from vegetables, is associated with a lower incidence of BC [7]. Additionally, a meta-analysis of six cohorts and six case-control studies found that intakes of flavanols and flavones, abundant in plant-based foods, offer protection against BC. This protection is particularly notable among postmenopausal women, which aligns with the findings of our subgroup analysis [8]. Wu et al. observed a significant trend of decreasing BC odds with increasing soy consumption in a meta-analysis of eight studies conducted in Asian populations, who are major consumers of soy [9]. Furthermore, other meta-analyses have reported comparable protective effects of soy on both pre-and postmenopausal women [10]. Some studies suggest that soy may exert antiestrogenic and antiproliferative effects in

Table 3 Association between portfolio diet score and odds of breast cancer

Variables	OR	95%CI	*P*-value
Portfolio diet score			
Crude	**0.934**	**0.890–0.980**	**0.006**
Adjusted	0.951	0.900-1.004	0.069
Plant protein (serving/day)			
Crude	**0.275**	**0.123–0.616**	**0.002**
Adjusted	**0.399**	**0.170–0.936**	**0.035**
Nuts (serving/day)			
Crude	1.463	0.744–2.878	0.270
Adjusted	1.708	0.813–3.585	0.157
Viscous fiber (serving/day)			
Crude	0.842	0.652–1.088	0.188
Adjusted	0.887	0.667–1.179	0.408
Plant MUFAs (serving/day)			
Crude	0.934	0.849–1.028	0.161
Adjusted	0.959	0.874–1.053	0.379
SFAs and cholesterol (serving/day)			
Crude	1.037	0.971–1.108	0.275
Adjusted	1.038	0.963–1.119	0.328
Phytosterols (mg/day)			
Crude	0.992	0.978–1.006	0.280
Adjusted	0.992	0.977–1.007	0.277

Abbreviations: OR, odds ratio; CI, confidence interval; MUFAs, monounsaturated fatty acids; SFAs, saturated fatty acids

Significant values are shown in bold

These values are odds ratios (95% CIs)

Obtained from logistic regression

-Adjusted for variables with p-value < 0.25 in multivariate analysis according to Table 2

Adjusted model: adjusted for age (years), marriage age (years), age at first pregnancy (years), breastfeeding time (years), BMI (kg/m^2), menopausal status (premenopause/post-menopause), family history of breast cancer (no/yes), wearing a bra at day (less than 12 h/more than 12 h), wearing a bra at night (no/yes), vitamin D (no/yes), omega-3 (no/yes), and herbal medicine (no/yes)

postmenopausal women [11, 12]. Epidemiological and preclinical research indicates that soy, as a rich source of plant-based protein, exerts its most protective effects against BC early in life due to its isoflavone content [13, 14]. Additionally, other studies proposed that plant proteins, such as soy, contain fibers and phytoestrogens that induce apoptosis [15].

Although we observed an association between the PDS and BC odds only in premenopausal women in our study, ascorbic acid, vitamin E, and other trace elements such as selenium— abundant in plant-based diets like the PD—possess antioxidant properties that help protect against free radical damage and maintain normal cellular function. The beneficial effects of vitamin C in cancer chemoprevention are primarily recognized for its potential to stimulate immune function, inhibit nitrosamine formation, minimize deoxyribonucleic acid (DNA) damage, and block the metabolic activation of carcinogens [16]. Our study did not identify a significant link between the PDS and its components, such as nuts, viscous fiber, plant MUFAs, SFAs, cholesterol, and phytosterols with BC odds in the total population. However, a similar finding of no effects on premenopausal BC odds, but a significant reduction in postmenopausal BC odds with high MUFA intake, was observed in the Nurses' Health Study and the Swedish Women's Lifestyle and Health cohort [17, 18]. The potential anti-tumor effects of MUFAs can be attributed to their antioxidant properties, ability to reduce chronic inflammation, and cholesterol-lowering effects [19–21]. Nonetheless, conflicting results have been observed in other studies; for example, some studies conducted in the US found significant increases in postmenopausal BC risk with higher MUFA intake [17, 22, 23].

In contrast to our study, which observed no association between SFA and cholesterol consumption and BC risk, a meta-analysis conducted by Boyd et al. reported a 19% increase in overall BC risk associated with higher SFA intake [24]. The findings of the European Prospective Investigation into Cancer and Nutrition (EPIC) cohort aligned with earlier meta-analyses, indicating an association between high SFA intake and a higher overall BC risk, with a hazard ratio of 1.13 [25]. In line with our study, no associations between nut consumption and BC risk were found in the Netherlands Cohort Study and the Malmö Diet and Cancer cohort [38–40]. This contrasts with findings from another study, which observed a 24% lower BC risk among women who consumed one

Table 4 Association between portfolio diet score and odds of breast cancer based on menopausal status

Variables	OR	95% CI	*P*-value	OR	95% CI	*P*-value
	Pre-menopause			**Post-menopause**		
Portfolio diet score						
Crude	**0.896**	**0.838–0.958**	**0.001**	0.992	0.922–1.068	0.838
Adjusted	**0.914**	**0.845–0.989**	**0.025**	0.961	0.878–1.052	0.392
Plant protein (serving/day)						
Crude	0.530	0.189–1.487	0.228	**0.134**	**0.039–0.467**	**0.002**
Adjusted	0.742	0.260–2.121	0.578	**0.078**	**0.015–0.399**	**0.002**
Nuts (serving/day)						
Crude	1.084	0.440–2.672	0.861	2.842	0.909–8.881	0.072
Adjusted	1.486	0.506–4.370	0.471	1.694	0.495–5.803	0.401
Viscous fiber (serving/day)						
Crude	**0.618**	**0.405–0.942**	**0.025**	1.062	0.767–1.470	0.717
Adjusted	0.737	0.452–1.201	0.221	0.976	0.665–1.433	0.902
Plant MUFAs (serving/day)						
Crude	0.902	0.770–1.057	0.201	0.960	0.856–1.077	0.486
Adjusted	0.939	0.805–1.095	0.421	0.956	0.849–1.077	0.459
SFAs and cholesterol (serving/day)						
Crude	1.090	0.992–1.198	0.073	0.982	0.893–1.081	0.711
Adjusted	1.112	0.996–1.242	0.058	0.966	0.864–1.080	0.541
Phytosterols (mg/day)						
Crude	**0.973**	**0.950–0.997**	**0.028**	1.006	0.988–1.027	0.527
Adjusted	0.982	0.955–1.010	0.212	0.995	0.974–1.017	0.671

Abbreviations: OR, odds ratio; CI, confidence interval; MUFAs, monounsaturated fatty acids; SFAs, saturated fatty acids

Significant values are shown in bold

These values are odds ratios (95% CIs)

Obtained from logistic regression

-Adjusted for variables with p-value < 0.25 in multivariate analysis according to Table 2

Adjusted model: adjusted for age (years), marriage age (years), age at first pregnancy (years), breastfeeding time (years), BMI (kg/m^2), family history of breast cancer (no/yes), wearing a bra at day (less than 12 h/more than 12 h), wearing a bra at night (no/yes), vitamin D (no/yes), omega-3 (no/yes), and herbal medicine (no/yes)

or more servings of nuts per day during ages 10–15 compared to those who consumed less than a serving per month [41]. Despite the belief that phytosterols regulate critical cellular processes such as proliferation and differentiation and exhibit anti-proliferative, anti-metastatic, and pro-apoptotic properties in the context of cancer, our findings did not indicate any association between phytosterols and BC risk [42]. These discrepancies highlight the necessity for further research to elucidate the impact of individual components of the PD, including the consumption of nuts, plant MUFAs, SFAs, and phytosterols, on BC risk. Overall, our findings underscore the PDS as a potential protective dietary approach against BC, particularly among premenopausal women. The combination of plant-based proteins and MUFAs within the PDS may work synergistically to lower BC risk by reducing inflammation, improving lipid profiles, affecting intestinal microbiota, and modulating estrogenic activity, as suggested by existing literature on plant-based diets [43–46].

Strengths and limitations

Our study provides an initial assessment of the relationship between the PDS and BC odds, making a significant contribution to the field. A notable strength is the adjustment for several potential confounding factors in the regression modeling. However, several limitations should be noted. The case-control design limits the ability to establish causality in the observed associations. While associations can be identified, the cross-sectional nature of the study restricts the ability to draw causal conclusions. Additionally, caution is warranted when generalizing the results to other regions, as the study was conducted in a single region. Furthermore, although the FFQ used in this study is validated, its reliance on participants' recall may introduce biases, potentially leading to either the underestimation or overestimation of nutrient intakes.

Conclusions

The present study investigated the relationship between the PDS and BC odds, focusing on various dietary components. We found that a higher PDS is associated with a significant reduction in BC odds among premenopausal women. Plant protein intake also showed a protective effect against BC in both the overall population and postmenopausal women. However, we did not find significant associations between the PDS and specific components such as nuts, viscous fiber, plant MUFAs, SFAs,

cholesterol, and phytosterols across the total population. These findings highlight the complex interaction between diet and BC odds, influenced by factors such as age and hormonal status.

Based on the findings of increasing BC mortality and the urgent need for effective preventive strategies [5], we recommend that dietary guidelines for BC prevention emphasize greater adherence to a plant-based diet, like the PD, with a particular focus on plant proteins. Incorporating foods rich in plant MUFAs and other beneficial components is also recommended. While the current study contributes novel insights into dietary strategies for BC prevention, further research is essential to elucidate the specific mechanisms and long-term effects of the PD and its components on BC odds across diverse populations and settings. Addressing these gaps will be crucial for developing targeted dietary recommendations aimed at reducing BC incidence and improving public health outcomes.

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Author contributions
S.Y., N.A., M.M., I.K., H.B.N. and M.N.; Contributed to writing the first draft. Z.S., M.N. and S.M.A.; Contributed to all data and statistical analysis and interpretation of data. M.N., S.Y., Z.S. and B.R.; Contributed to the research concept, supervised the work, and revised the manuscript. All authors read and approved the final manuscript.

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Data availability
The datasets used and/or analyzed during the current study are available from the corresponding author on reasonable request.

Declarations

Ethics approval and consent to participate
This study was conducted in accordance with the ethical standards of the Declaration of Helsinki and was approved by the Medical Research and Ethics Committee of Shahid Beheshti University of Medical Sciences. All participants read and signed the informed consent form.

Consent for publication
Not applicable.

Competing interests
The authors declare no competing interests.

Conflict of interest
Not applicable.

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